Ground-based Biomechanical Analyses of Resistance Exercise Using the Advanced Resistive Exercise Device

Completed Technology Project (2009 - 2010)

Project Introduction

The new integrated resistance and aerobic training study (SPRINT) exercise prescription is being designed using ground-based evidence with the intent of increasing the loads experienced by the musculoskeletal system during in-flight exercise. Prescription optimization is dependent upon a complete understanding of exercise biomechanics in order to include exercises that are most beneficial to increasing crewmember health. Furthermore, variations in exercise biomechanics of specific exercises, such as the range of motion during the performance of the parallel squat, could have large influences upon the loads experienced by the musculoskeletal system. A detailed biomechanical analysis is required to determine which variations lead to the greatest site-specific joint loading forces and can be used to inform the optimal exercise prescription. The objective of this project was to determine the joint loads that occur during exercise in microgravity on the Advanced Resistive Exercise Device (ARED). The goal is to determine the best exercises for use during crewmember exercise during long-term missions.

There are various complexities with performing in-flight investigations. In order to maximize the potential for the most relevant data to be collected with minimal impact on crew time, we propose a two-phase program. Biomechanical analyses need to occur during actual exercise in microgravity to ensure optimal application of the results. However, since crew time is limited, ground-based evaluations should occur prior to in-flight data collection to ensure that the analyses performed on International Space Station (ISS) are completed as efficiently as possible. We propose to complete the analysis in three phases. Phase 1, which is detailed in this study, involved a detailed data collection on ground while subjects performed variations of squat and deadlift exercises on the ARED. Variations of each exercise included placement of the feet, speed of the lift, and range of motion and were examined. A computational model was used to compute joint loads and torques during each exercise. Six subjects (3 M/3 F) of small, medium, and large body types as described by NASA anthropometric standards were tested. The purpose of this investigation was to quantify the joint loading that occurred during typical resistance exercise on the ARED. The goal was to better understand the kinematic and kinetic similarities between exercise variations and to determine a subset of exercises that will be included in a future proposal that will include a biomechanical analysis of exercise on the ISS using the subset of exercises determined during phase 2.

Anticipated Benefits

Resistance exercise is a common activity performed by individuals wishing to increase muscular strength and bone health. Crewmembers perform squat and deadlift exercise to load the lower extremity and core musculature and the axial skeleton. Each exercise is fundamentally similar in that a subject performs hip, knee, and ankle flexion and extension as a load is lowered and

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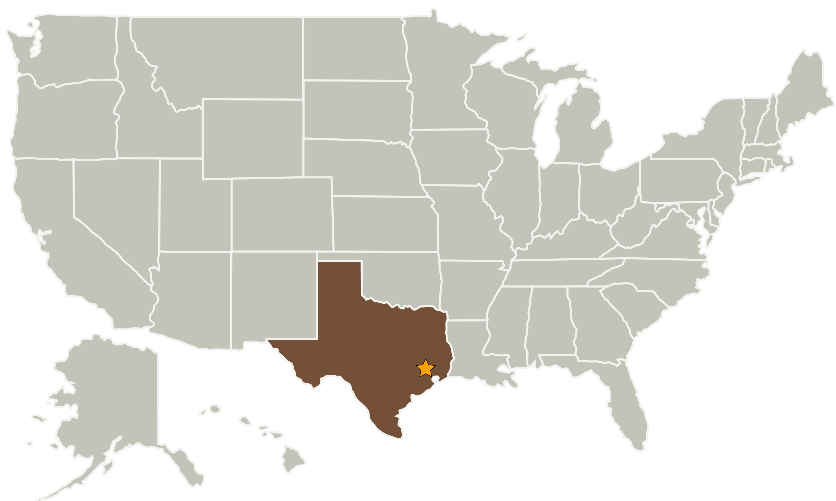
raised. During the lowering phase, musculature primarily acts eccentrically, while during the raise musculature primarily acts concentrically. Squat and deadlift exercises are common activities performed in exercise programs used by athletes and during rehabilitation from injury.

Each exercise can be modified by increasing or decreasing stance width, movement velocity, and/or range of motion. Although the fundamental movement remains the same, these variations or combinations thereof may result in differences in long-term training effects. In order for practitioners to better understand and utilize these variations in creating optimal exercise programs, the joint motions and loads need to be quantified. This research, because it was performed in normal gravity, is beneficial to strength coaches, rehabilitation personnel, and scientists who use squat and deadlift exercise as a part of their exercise programs. In addition, this is the first study to quantify the hip joint motions in the frontal and transverse planes, which is important in differentiating between exercise variations and better understanding why slight variations load the musculoskeletal system differently.

Primary U.S. Work Locations and Key Partners



Organizational Responsibility

Responsible Mission Directorate:

Space Operations Mission Directorate (SOMD)

Lead Center / Facility:

Johnson Space Center (JSC)

Responsible Program:

Human Spaceflight Capabilities

Project Management

Program Director:

David K Baumann

Project Manager:

Peter Norsk

Principal Investigator:

John K Dewitt

Co-Investigators:

Renita S Fincke
Lori L Ploutz-snyder
Kirk L English
Mark E Guilliams
Rachel L Logan

Organizations Performing Work	Role	Type	Location
★Johnson Space Center(JSC)	Lead Organization	NASA Center	Houston, Texas
KBRwyle, Inc.	Supporting Organization	Industry	Houston, Texas
Midwestern University, Chicago College of Osteopathic Medicine	Supporting Organization	Academia	Chicago, Illinois
Universities Space Research Association(USRA)	Supporting Organization	R&D Center	Huntsville, Alabama

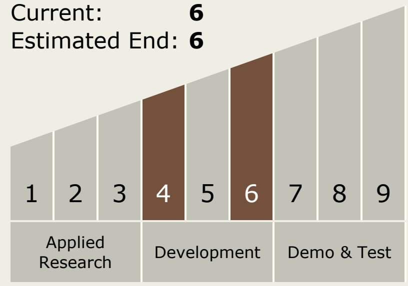
Primary U.S. Work Locations
Texas

Project Transitions

July 2009: Project Start

Technology Maturity (TRL)

Start: **4**
Current: **6**
Estimated End: **6**



Technology Areas

Primary:

- TX06 Human Health, Life Support, and Habitation Systems
  - └ TX06.3 Human Health and Performance
    - └ TX06.3.2 Prevention and Countermeasures

Target Destinations

The Moon, Mars

October 2010: Closed out

Closeout Summary: This investigation was completed in 2010, and a final report was submitted to NASA.The purpose of t his investigation was to quantify the joint kinematics and kinetics that occur during squat and deadlift exercise on the ARED to inform a future proposal that will include a biomechanical analysis of exercise on the ISS. Six subjects (3m/3f) were test ed while performing single legged squats, normal squats, increased range of motion squats, wide stance squats, fast squat s, reduced range of motion squats, normal deadlift, and sumo deadlift. Ground reaction force (GRF) and motion capture dat a were collected as each subject performed a single repetition using a load that approximated their 10 repetition maximum. Testing loads were determined during an earlier training session. Three dimensional joint kinematics and kinetics were com puted using a standard inverse dynamics approach. GRF data indicated that peak loads were dependent upon exercise type and that the peak GRF did not always occur at the same time during a repetition depending upon the exercise. Bilateral join t kinematics were generally symmetrical; however, hip adduction and rotation displayed increased bilateral asymmetry. Joi nt kinetics differed between exercise types although there were no specific trends across all variables. In general during the downward motion, work was performed on the hip and knee extensors for all exercises, and work was performed by the hip and knee extensors during the upward motion. Positive and negative work for hip adduction/abduction, hip internal/externa l rotation, and ankle flexion varied across exercises. Bilateral joint kinetics were asymmetrical, which may reflect a property of ARED that needs further study.Based on our results, we suggest that the exercises included in a future flight study includ e, along with the justification:1) Normal Squat: A baseline measure2) Single Legged Squat: Increased net hip torque and o nly exercise inducing hip adduction3) Wide Normal Squat: Hip adduction and rotation kinematics suggest femoral head load ing differences4) Normal Deadlift: Baseline measure, but with different kinematics than the squatFurthermore, we suggest t he following:1) Increasing the subject size of the current study to allow for standard statistical analyses2) Retest of current subjects bilateral symmetry using a free weight condition3) Further study of the FS condition relative to free weights to bett er understand joint kinetic differencesAlthough IR (increased range of motion) squats had larger kinetic values than others, variation was also increased because of between subject differences. We did not recommend this lift because of the larger s ubject variation, but this lift should also be considered in a future study.

Stories

Abstracts for Journals and Proceedings
(https://techport.nasa.gov/file/46430)

Abstracts for Journals and Proceedings
(https://techport.nasa.gov/file/46431)

Articles in Peer-reviewed Journals
(https://techport.nasa.gov/file/46432)

Project Website:

https://taskbook.nasaprs.com